ENGR 350 - Mechanics of Materials, Fall 2013

Homework #4

Due: Mon., Sept. 22

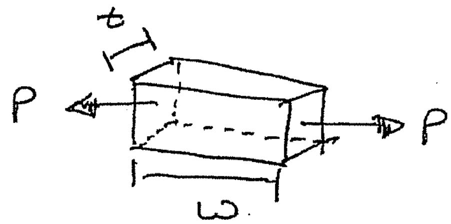
1. Problem P4.1, p. 79
2. Problem P4.4, p. 79
3. Problem P4.6, p. 80
4. Problem P4.11, p. 81

(all problems are from the textbook).

4.1

$w = 25\ mm \qquad t = 16\ mm$

$P = 145\ kN$



a) $\sigma_y = 550\ MPa$

$$\sigma = \frac{F}{A} = \frac{(145\ kN)(1000\ N/kN)}{(25\ mm)(16\ mm)}$$

$$= 362.5\ MPa$$

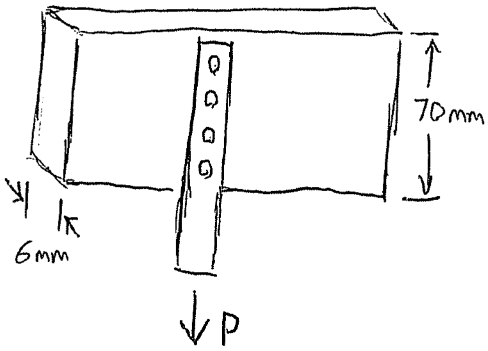
$$FS = \frac{\sigma_y}{\sigma_{act}} = \frac{550\ MPa}{362.5\ MPa} = \boxed{1.517}$$

B) $\sigma_u = 1,100\ MPa$

$$F_s = \frac{\sigma_u}{\sigma_{act}}$$

$$= \frac{1100\ MPa}{362.5\ MPa} = \boxed{3.03}$$

4.4) <Given>



Screws:

$\sigma_s = 165\,MPa = \tau_{us}$

$SF_u = 3.0$

Metal Bar:

$\sigma_y = 250\,MPa$

$\sigma_u = 350\,MPa$

$SF_B = 3.0$

$SF_Y = 1.67$

<Goal>

Allowable load P

<Solution>

Bar (normal stress):

$$\sigma_{allow} = \frac{\sigma_y}{SF_y} = \frac{250\,MPa}{1.67} = 149.7\,MPa$$

$$P_{allow} = \sigma_{allow} A_{bar}$$

$$= 149.7\,MPa\,(70\,mm)(6\,mm)$$

$$= 62{,}874\,N$$

Lag Screws (shear stress):

$$\tau_{allow} = \frac{\tau_{us}}{SF_u} = \frac{165\,MPa}{3.0} = 55.0\,MPa$$

$$A_{screw} = \pi d^2/4 = \pi(22\,mm)^2/4 = 380.1\,mm^2$$

$$V_{screw} = (55\,N/mm^2)(380.1\,mm^2) = 20{,}907\,N$$

$$P_{allow} = 4\text{ screws}\,(20{,}907\,N/\text{screw}) = 83{,}630\,N$$

Bar (bearing stress):

$$\sigma_{allow} = \frac{\sigma_y}{SF_B} = \frac{\sigma_y}{SF_B} = \frac{350\ MPa}{3.0} = 116.67\ MPa$$

$$F_B = 116.7\ N/mm^2\,(22\ mm)(6\ mm) = 15{,}400\ N$$

$$P_{allow} = 4F_B = 4(15{,}400\ N) = 61{,}600\ N$$

Allowed Load:

$$P_{allow} = 61{,}600\ N = \boxed{61.6\ kN}$$

Problem 4.6

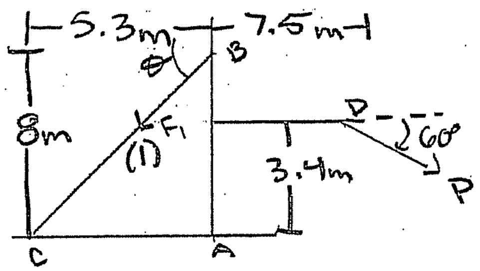
Given: Rigid structure supported by $D_1 = 35$ mm rod tie rod connected at B and C by D = 30 mm double shear

$D_2 = 30$ mm pin single shear

$\sigma_{Y1} = 250$ MPa $\sigma_U = 330$ MPa P = 50 kN

Find:
a) normal stress in rod 1
b) shearing stress in pins at A and B
c) FOS → tie rod 1
d) FOS pins A and B

Solution:



a)

$$\tan\theta = \frac{8\text{ m}}{5.3\text{ m}}$$

$$= 1.50943$$

$$\theta = 56.4755°$$

$$\Sigma F_x = P\cos 60° - F_1\cos 56.4755° + A_x$$

$$\Sigma F_y = -P\sin 60° - F_1\sin 56.4755 + A_y = 0$$

$$\Sigma M_A = (F_1\cos 56.475)(8\text{m}) - (P\cos 60°)(3.4\text{m}) - P\sin 60)(7.5) = 0$$

$$F_1 = \frac{P(3.4\text{m})\cos 60 + (7.5)\sin 60}{8\text{m}(\cos 56.4755)}$$

$$= \frac{50(3.4)\cos 60 + (7.5)(\sin 60)}{8(\cos 56.475)}$$

$$= 92.7405 \text{ kN}$$

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMET

$A_x = F_1 \cos 56.4755 - P\cos 60$

$= (92.7405)\cos 56.4755 - 50(\cos 60)$

$= 26.2199$ kN

$A_y = F_1 \sin 56.4755 + P\sin 60$

$= (92.7405)\sin(56.4755) + 50 \sin 60$

$= 120.6144$ kN

$|A| = \sqrt{A_x^2 + A_y^2}$

$= \sqrt{(26.2199)^2 + (120.6144)^2}$

$= 123.4314$ kN

$A_1 = \frac{\pi}{4}(35)^2$

$= 962.1127 \text{ mm}^2$

$\sigma_1 = \frac{F_1}{A_1}$

$= \frac{92740.5 \text{ N}}{962.1127 \text{ mm}^2}$

$\boxed{= 96.39 \text{ MPa}}$

b) $A_{v,A} = \frac{\pi}{4}(30)^2$

$= 706.858 \text{ mm}^2$

$\tau_A = \frac{123431.4}{706.8583}$

$\boxed{= 174.619 \text{ MPa}}$

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMET

$$\tau_B = \frac{92740.5}{904.7786}$$

$$\boxed{= 102.5008 \text{ MPa}}$$

c $FS_1 = \frac{\tau_U}{\tau_A}$

$$= \frac{250 \text{ MPa}}{96.39 \text{ MPa}}$$

$$\boxed{= 2.59}$$

d $FS_A = \frac{\tau_U}{\tau_A}$

$$= \frac{330 \text{ MPa}}{174.6197 \text{ MPa}}$$

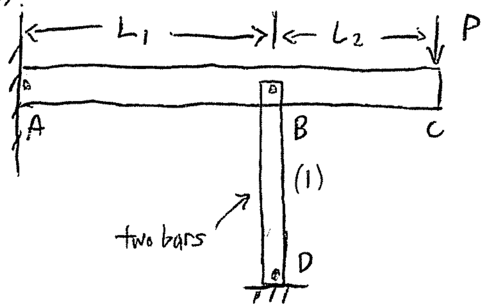
$$\boxed{= 1.89}$$

$FS_B = \frac{\tau_U}{\tau_B}$

$$= \frac{330 \text{ MPa}}{102.5008 \text{ MPa}}$$

$$\boxed{= 3.22}$$

4.11) (Given)



$L_1 = 36\text{ in}$

$L_2 = 24\text{ in}$

$d_A = d_B = d_D = 0.5\text{ in}$

$\sigma_y = 36\text{ ksi}$ (bars)

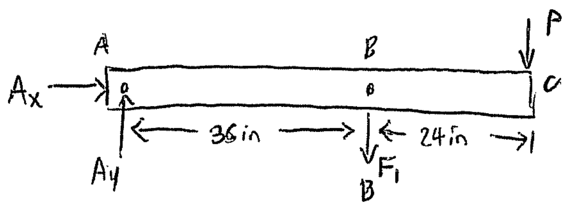
$\sigma_u = 72\text{ ksi}$ (pins) $= \tau_u$

$SF = 3.0$

⟨Goal⟩

Allowable load P

⟨Solution⟩



$\overset{+}{\rightarrow} \Sigma F_x = A_x = 0$

$+\uparrow \Sigma F_y = A_y - P - F_1 = 0$

$\circlearrowleft + \Sigma M_A = -L_1 F_1 - (L_1 + L_2) P = 0$

$$F_1 = -\left(\frac{L_1 + L_2}{L_1}\right) P = -\left(\frac{36\text{ in} + 24\text{ in}}{36\text{ in}}\right) P = -1.667 P$$

$$A_y = P + F_1 = P + (-1.667 P) = 0.667 P$$

$$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(0)^2 + (-0.667 P)^2} = 0.667 P$$

strut (1):

$$\sigma_{allow} = \frac{\sigma_y}{SF} = \frac{36\text{ ksi}}{3.0} = 12.0\text{ ksi}$$

$$F_{allow} = \sigma_{allow} A = 12\text{ ksi}\,(2 \cdot 2\text{ in} \cdot 0.25\text{ in}) = 12.0\text{ kips}$$

(← area of strut)

$$P_{max} \leq \frac{F_{allow}}{1.667} = \frac{12.0\text{ kips}}{1.667} = 7.20\text{ kips}$$

Pins:

$$\tau_{allow} = \frac{\tau_u}{SF} = \frac{72\,ksi}{3.0} = 24.0\,ksi$$

$$A_{pin} = \pi(0.5\,in)^2/4 = 0.1964\,in^2$$

Pin A:

$$A_{allow} = \tau_{allow} A_{pin} = 24.0\,ksi\,(0.1964\,in^2) = 4.7124\,Kips$$

$$P_{max} \leq \frac{A_{allow}}{0.667} = \frac{4.7124\,Kips}{0.667} = 7.07\,Kips$$

Pin B and Pin D:

$$F_{allow} = \tau_{allow} A_{pin} = 24\,ksi\,(2)(0.19634\,in^2) = 9.425\,Kips$$

$$P_{max} \leq \frac{F_{allow}}{1.667} = \frac{9.425\,kips}{1.667} = 5.655\,kips \Rightarrow \text{lowest value}$$

Maximum load:

$$P_{max} = 5.6549\,Kips = \boxed{5.65\,Kips}$$